IMPACT OF TREES ON THE AGRICULTURAL PERFORMANCE OF SMALLHOLDER FARMING SYSTEMS AT LANDSCAPE SCALE IN SENEGAL

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INTRODUCTION

Management of isolated trees has long been a key **food security and livelihood strategy** while improving farmers' resilience to climate change in Africa [Garrity et al., 2010].

Agroforestry provides a wide range of **ecosystems services** : diversification of incomes and household nutrition, enhance soil fertility and boosting crop yields of annual crops [Sinare & Gordon, 2015].

A myriad of studies on understanding effects of trees on crop productivity at tree scale but current knowledge on the i**mpact of parkland structuring** on agrosystems productivity is limited.

In sub-saharan Africa

30% of agricultural land & **40%** of people living in landscape with tree cover > 10% [Zomer et al., 2014]

OBJECTIVES

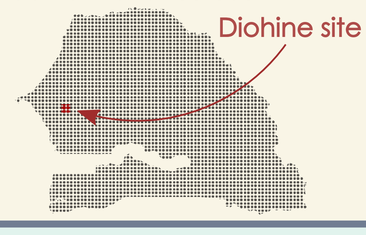
Remote sensing | **Landscape ecology** | **Statistical modelling**

1-To **evidence the contribution of isolated trees** to the agricultural performance of smallholder farming systems at landscape scale.

2-To improve **the assessment of crop yields** integrating the effects of isolated trees at landscape scale.

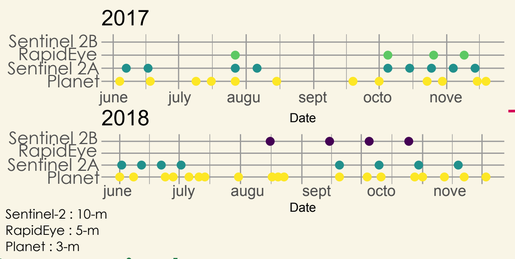
Case study :
Faidherbia parkland of Senegal

° *Faidherbia albida* parkland
° Main crops : Millet & Groundnut in rotation
° Annual rainfall : 400-800 mm



METHODS

Satellite images



Agronomical survey

69 farmers' fields over 2017 & 2018 cropping season covering a landscape diversity gradient

Millet (n=50)

Groundnut (n=19)

Agricultural practices & Phenology

Tree inventory

Yield components at harvest

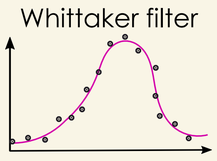
Images processing

1-Vegetation productivity proxies

NDVI
CIGreen
GDVI
MSAVI
NDWI
PSRINIR

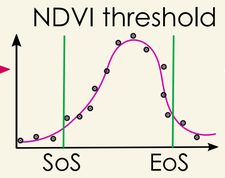
2-Daily interpolation

Whittaker filter



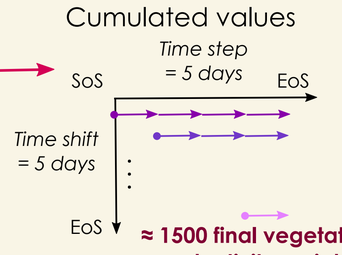
3-Phenological metrics

NDVI threshold



4-Integration

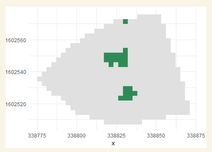
Cumulated values



≈ 1500 final vegetation productivity variables

5-Parkland composition proxies

NDVI threshold in June



Number of trees

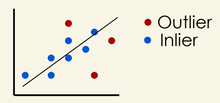
Woody cover

Yield estimates

Linear Regression model
5-fold cross validation

With tree | Without tree

RANSAC*
Coefficient optimization

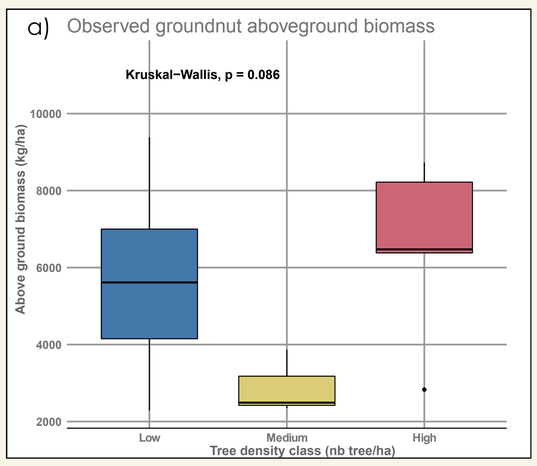


Best model selection
R² & RRMSE

*RANdom SAmple Consensus

RESULTS

Trees effect at landscape scale



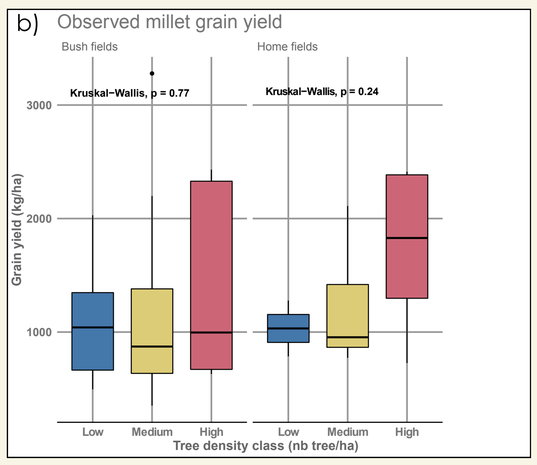


Fig 1. Analysis of observed groundnut aboveground biomass (AGB) (a) and millet grain yield (GY) (b) according to tree density classes obtained with a k-means clustering. Medians are compared with a Kruskal-Wallis test. A comparison between home fields and bush fields is made for millet only since groundnut is rarely cultivated on home fields.

- Marginally significant difference (p-value<10%) of groundnut AGB according to tree density classes with a **slight increase in observed AGB** with increase in tree density.
- No significant difference of millet GY according to tree density classes excepted for **home fields** where GY **increased by 50%** with increase in tree density.
- Overall, millet GY are more variable in bush fields.

From satellite information to yield estimates

Sensitivity analysis to tree information and vegetation productivity proxies - Millet example

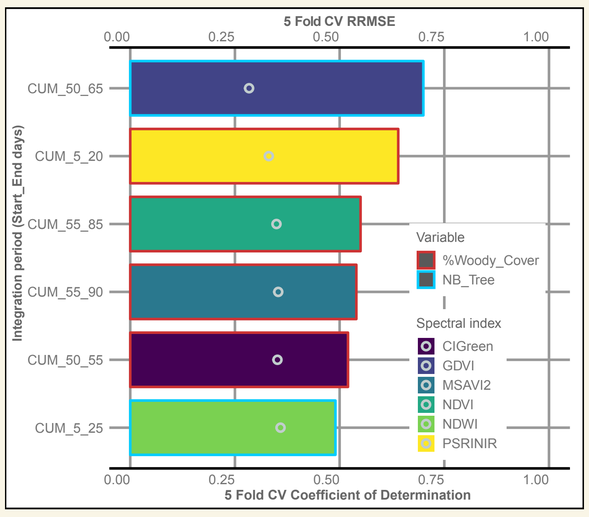


Fig 2. 5-fold cross validation R² and RMSE for the best integration period of each vegetation productivity index with and without parkland structuring information added to the millet GY.

- Best integration periods mainly concern **reproductive phases** (grain filling to physiological maturity, 50 to 90 days after emergence).
- For all vegetation productivity proxies, **integrating parklands structuring information increased models accuracy** with R² greater than 0.5 (NDWI excepted).

Yield estimates

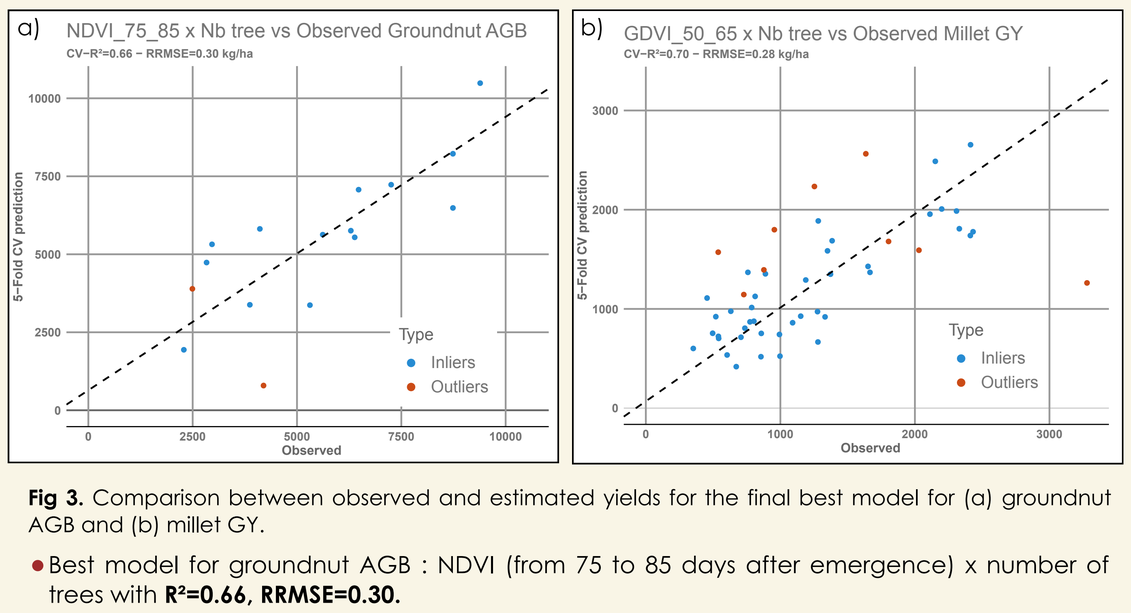


Fig 3. Comparison between observed and estimated yields for the final best model for (a) groundnut AGB and (b) millet GY.

- Best model for groundnut AGB : NDVI (from 75 to 85 days after emergence) x number of trees with **R²=0.66, RRMSE=0.30.**
- Best model for millet GY : GDVI (from 50 to 65 days after emergence) x number of trees for with **R²=0.70, RRMSE=0.28.**
- Improvement in the remote sensing crop yield models at landscape scale confirms that the **spatial extent of tree influence** driven by lateral roots influence is **beyond the canopy crown area** [Sileshi, 2016].

CONCLUSIONS

- Results on tree influence **at landscape scale are not fully in line** with studies conducted at tree scale showing an improvement of yield under *F. albida* crown [Louppe, 1996].
- While *F.albida* is the dominant specie of the parkland, our method (remote sensing and landscape ecology) didn't distinguish the different tree species present in the parkland. This suggests that the well-known 'fertility hotspot' of *F. albida* can be **tempered at landscape scale by the tree specific diversity**.
- Using a remote sensing based model, first results of this study highlighted the **need to integrate parklands structuring information** as mean to account for isolated trees effects (all species taken together) to **improve the agricultural assessment performance** at landscape scale.
- Further analyses will address the intra-fields variability (e.g. the distance decay effects) and inter-fields variability in response to trees effects on crop productivity.

References

Garrity et al., 2010. Evergreen Agriculture: a robust approach to sustainable food security in Africa. Food Secur. 2, 197–214.

Louppe et al., 1996. Influence de Faidherbia albida sur l'arachide et le mil au Sénégal, in: Les Parcs à Faidherbia" (Acacia Albida Parklands), Cahiers Scientifiques Du Cirad-Forêt N°12. CIRAD, Montpellier, France, pp. 123–139.

Sileshi., 2016. The magnitude and spatial extent of influence of Faidherbia albida trees on soil properties and primary productivity in drylands. J. Arid Environ. 132, 1–14.

Sinare & Gordon., 2015. Ecosystem services from woody vegetation on agricultural lands use in Sudano-Sahelian West Africa. Agric. Ecosyst. Environ. 200,186-199.

Zomer., 2014. Trees on farms: an update and reanalysis of agroforestry's global extent and socio-ecological characteristics (No. 179). Bogor, Indonesia.

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